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THE EFFECT OF OVERLEARNING AND MAGNITUDE  
OF REWARD ON EXTINCTION AND REVERSAL  
IN DISCRIMINATION LEARNING

by

Peter Furstenau



A THESIS

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UNIVERSITY OF ALBERTA  
FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommend to the Faculty of Graduate studies for acceptance, a thesis entitled "The Effect of Overlearning and Magnitude of Reward on Extinction and Reversal in Discrimination Learning," submitted by Peter Furstenau in partial fulfilment of the requirements for the degree of Master of Science.





### Abstract

An experiment was performed investigating the effect of magnitude of reward and level of acquisition training on extinction performance and reversal performance in a black-white discrimination task. Eighty rats (eight groups) were run with six groups constituting a  $2 \times 3$  factorial design in which the independent variables were two levels of acquisition training (40 or 100 trials) and three levels of reward magnitude (2, 4 or 8 Noyes pellets). These six groups received first acquisition training, then 60 extinction trials, and finally reversal training to criterion. In addition to these six groups there were two groups who had either 40 or 100 acquisition trials with a reward magnitude of 8 pellets, and then proceeded directly to reversal training.

The results showed that, compared with nonovertraining, overtraining led to a greater degree of extinction and faster reversal with large reward; with small reward overtraining led to lesser degree of extinction and slower reversal. For large reward magnitude groups, an interpolated extinction period between acquisitions and reversal led to faster reversal learning. An ORE (overlearning reversal effect) was found only in large reward magnitude groups that did not have the interpolated extinction training.



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These findings indicate that speed of reversal learning is related to the level of extinction of original learning, and that extinction of original learning is an important process in reversal learning.

The results tend to support the extinction analysis of the ORE.





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Peter Furstenau



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## Introduction

The overlearning reversal effect (ORE) refers to the finding that under some conditions the reversal of a discrimination task (i.e., learning to respond to the formerly negative stimulus) is facilitated by additional trials beyond a performance criterion on the original learning. One of the earliest overtraining studies (but not overtraining reversal studies) was reported by Jackson (1932). He found differential maze performance in rats due to the amount of prior training in a different maze. According to Jackson the transfer effect "... was large and negative when there had been slight overlearning on the first maze, but become positive, although small, when overlearning had been carried further." The current interest in the ORE phenomenon was generated by Reid (1953) with an experiment designed to bear on the continuity-noncontinuity issue of learning. At that time continuity theorists would have predicted that overtraining on a discrimination task would lead to a reverse ORE, that is, overtrained Ss would reverse slower than criterion trained Ss. It was reasoned that overtraining would lead to a stronger original habit and greater interference in reversal, since the original habit had to be extinguished in reversal.

On the basis of Harlow's (1949) finding that animals solve discrimination problems faster the more problems





they have solved previously, Reid (1953) predicted that overtraining on one problem would have a similar facilitative effect on reversal training. Contrary to predictions from continuity theory, Reid found that rats given 150 post-criterion trials on a black-white discrimination in a Y-maze performed the reversal of that discrimination in fewer trials than rats trained only to a criterion. Reid attempted to place his results within the framework of continuity theory by assuming that the original learning involved not only the attaching of specific habits to positive and negative cues, but in addition "... learning a response of discriminating, such as a clear-cut looking at one stimulus card, looking at the other stimulus card, and immediately making a response to the correct card." This mediating response was a concept similar to Wykoff's 'observing response' (1952), and would occur, and would be reinforced consistently, only after mastery of the discrimination task. During reversal the overtrained Ss have this response which would lead to continued 'observing' of the relevant stimulus dimension, and subsequently faster reversal compared to criterion trained Ss who had not been responding consistently within the relevant stimulus dimension.

Reid's account of the ORE was somewhat weakened by an experiment by Birch, Ison and Sperling (1960) in which an ORE based on response latency was found using the



successive stimulus presentation of a brightness discrimination. With successive stimulus presentation the response of discriminating could not occur since on each trial only one stimulus was presented. In addition, the facilitative effect leading to the ORE appeared to be located in the extinction of the original responses in the reversal stage. Birch et al (1960) found that the overtrained animals reached the reversal criterion sooner. The reversal criterion was defined as the first day in which all five latencies to the positive stimulus were less than the smallest latency to the negative stimulus. The acquisition rate of reversal learning, as measured by latencies to the now-positive stimulus was similar for both the overtrained and criterion trained groups. The overtrained group however extinguished faster (in terms of response latency) its response to the previously positive stimulus. In this study then, the superior performance of the overtrained group appeared to be due to the faster extinction of response tendencies to the previously positive stimulus. Birch et al pointed out that this finding does not necessarily imply that the response of discriminating is not operative in the simultaneous choice discrimination; rather the study suggests that other variables, such as differential extinction, also determine the ORE.

In Reid's analysis of the ORE, this effect is due to the non-specific effect of learning to discriminate.



Another set of experiments which Reid's hypothesis does not account for involve nonreversal shifts, in which it is found that overtraining on the original discrimination does not facilitate reversal on a previously presented, but irrelevant discrimination. Using a Lashley jumping stand Mackintosh (1962) trained some SS on a reversal shift, others on a nonreversal shift. Overtraining facilitated a reversal shift, but retarded a nonreversal shift. Reid's analysis of the ORE would have led to the prediction that both types of reversals would have been facilitated with overtraining.

Since Reid's (1953) unexpected results, a large number of ORE studies have appeared, which have been summarized in several reviews (Mackintosh, 1965a; Paul, 1965; Sperling, 1965a, 1965b). Although there have been a number of studies which have reported finding the ORE (Birnbau, 1964; Brookshire, Warren & Ball, 1961; Bruner, Mandler, O'Dowd & Wallach, 1958; Capaldi, 1963; Capaldi & Stevenson, 1957; Hooper, 1967; Ison & Birch, 1961; Mackintosh, 1962, 1963; North & Clayton, 1959; Pubols, 1956; Sasaki, 1960; Theios & Blosser, 1965a, 1965b), there have been many studies which have failed to find an ORE (Clayton 1963a, 1963b; D'Amato & Jagoda, 1962; D'Amato & Schiff, 1964; Erlebacher, 1963; Hill, Spear & Clayton, 1962; Hirayoshi, & Warren 1965; Kendler & Kimm, 1964, 1967; Mackintosh, 1965; Theios & Blosser, 1965). Because of these





inconsistent results there have been attempts to determine the variables controlling the ORE, and to devise theoretical models which predict the ORE in some cases, but not in others. Some of the variables that have been unsuccessfully manipulated in overtraining reversal studies are the intertrial intervals (Capaldi & Stevenson, 1957), deprivation level (Bruner et al, 1958), discriminability of difference between acquisition and reversal (D'Amato & Schiff, 1964), and strain differences (D'Amato & Schiff, 1964).

Basically there have been two sets of models to account for the ORE. Extinction hypotheses have attempted to derive the ORE on the basis of faster extinction of the original learning in reversal learning for overtrained Ss. Attention models have as their main mechanism to account for the ORE the differential attention to the relevant stimulus dimension for overtrained and non-overtrained Ss.

According to the extinction hypothesis a reversal experiment involves three stages: (1) acquisition of the discrimination, (2) extinction of the discrimination, and (3) acquisition of the reversal of the discrimination. Usually stages (2) and (3) overlap. Overtraining facilitates reversal learning because it shortens the extinction phase.

An early model by Capaldi and Stevenson (1957) which attempted to explain the ORE on the basis of differential extinction hypothesized that, compared to criterion training,



overtraining leads to an easier discrimination between acquisition and extinction and therefore faster extinction. Since in the model reversal learning involves the extinction of the original learning, the variables, such as amount of training, that result in differential extinction performance should also lead to differential reversal performance.

In Hull's (1943) theory, extinction was a monotonic, positive function of the amount of acquisition training. Hullian S-R theory attributed no special motivating or inhibiting effects to nonreinforcement or extinction. Resistance to extinction was a function of habit strength, or operationally, the number of reinforced learning trials. Later, however, S-R theorists like Amsel (1958, 1962) attributed motivational properties to the absence of reward in extinction. According to Amsel, nonreinforcement leads to frustration, which leads to the inhibition of previously reinforced responses, or extinction. One implication of the frustration hypothesis is that greater frustration during experimental extinction leads to faster extinction. Since the amount of frustration is an increasing function of the strength of the conditioned anticipatory goal responses, which increases with the number and size of rewards, the frustration hypothesis predicts that overtraining leads to more frustration and, therefore, faster extinction than criterion training. In support of this hypothesis a



number of studies investigating the effect of amount of training on extinction performance in a straight alley apparatus have shown that overtraining leads to faster extinction than criterion training (Capaldi, 1958; Ison, 1962; Wagner, 1963;). This overtraining effect on extinction performance appears to depend, at least partially, on an interaction with reward magnitude. Using a straight runway apparatus Ison (1962) found that with large reward overtraining leads to decreased resistance to extinction (i.e., increased latencies) than nonovertraining whereas with small reward the reverse was observed. Other studies (Armus, 1959; Hulse, 1958; Reynolds & Siegel, 1961) in which acquisition training was not varied, have shown that a large magnitude of reward in acquisition leads to faster extinction than a small reward magnitude.

The implication for reversal learning of these extinction studies is obvious. On the basis of the frustration hypothesis and the extinction hypothesis of the ORE one would predict that either an increase in amount of reward per trial or an increase in the number of trials (using at least a moderate magnitude of reward) would lead to better reversal performance.

Theios and Blosser (1965a, 1965b) have presented evidence for a model related to the frustration hypothesis which takes into account both the variables of amount of training and amount of reward in predicting extinction







and/or reversal performance. The model states that (a) habit strength (H) is an increasing exponential function of the number of instrumental responses in acquisition, (b) incentive motivation (K) is an increasing exponential function of the number of appetitively rewarded training trials, (c) the H-function reaches asymptotic level before the K-function, and (d) the asymptote of K is directly related to the magnitude and quality of reward. According to the model". . . the expected number of responses to an extinction or reversal criterion is a linear function of the difference between H and K at the start of extinction or reversal learning." (Theios and Blosser, 1965a). Since with overtraining K increases while H is asymptotic, the difference between H and K decreases producing the usual ORE. Theios and Blosser assert that many studies which have failed to find an ORE can be accounted for by this model on the basis of size of reward. If rewards are small then the asymptote of the K function is low, which would result in small differences along the K function between overtrained and criterion trained Ss. Consequently H-K differences would be similar for nonovertrained and overtrained Ss, and, according to the model, no ORE would occur. Although there are exceptions, the majority of the ORE studies bear out Theios and Blosser's prediction. The following studies have used large rewards such as 10-20 seconds access to wet mash or .150-1.00 gm. food and have



found an ORE: Pubols (1956), Bruner et al (1958), Komaki (1961), Mackintosh (1962, 1963, 1965b), Capaldi (1963), Theios and Blosser (1965a, 1965b), and Hooper (1967).

The following studies using small rewards (less than 10 seconds access or less than 150 mg. food) have failed to find an ORE: D'Amato and Jagoda (1962), Hill et al (1962), Clayton (1963), Hill and Spear (1963), Mackintosh (1965), Erlebacher (1963), Kendler and Kimm (1964, 1967). The success and failure of finding the ORE in these studies on the basis of size of reward support Theios and Blosser's model.

There are, however, studies which have used large rewards (as defined above) and have failed to find an ORE: (Clayton, 1965; D'Amato and Schiff, 1964; Kendler and Kim, 1964, 1967), and studies which have used small rewards and have reported an ORE (Ison, Birch and Sperling, 1961; North and Clayton, 1959). The exceptions to the expectations of the Theios and Blosser model suggest that variables other than the magnitude of reward interact with amount of training to determine reversal performance.

Sutherland (1964) and Mackintosh (1965a) have proposed an attention model of discrimination learning in which they attempt to account for the ORE in terms of attention. Their concept of attention is similar to Reid's (1953) discriminating response in that both concepts involve the idea that the animals learn about the cues in their environment. The concept of attention differs from Reid's discrimination



response in that it is proposed that the animal's learning about the cues in its environment is selective, depending on the amount of attention focused on it whereas for Reid it is nonselective. According to Mackintosh (1965a) the concept of attention concerns the selective or filtering processes in perception.

Animals (particularly lower animals) have nervous systems of limited size and therefore of limited capacity for processing and storing information. Thus they are confronted with the problem of selection. At some stage they must discard irrelevant or redundant information so as not to interfere with the storage of important information. This line of argument would seem to provide a general rationale for postulating, as Broadhurst does, the existence of filtering devices in the nervous system. (Mackintosh, 1965, p. 124)

Sutherland (1964) and Mackintosh (1965a) have proposed a two-stage model similar to Reid's where in order to solve a discrimination problem the S has to (1) learn to attend to the relevant stimulus dimension (e.g. brightness of the stimulus material) and (2) establish appropriate choice responses. The ORE is accounted for in this model by assuming that the S is still learning to attend with post-criterion trials, when the learning of the choice responses has reached asymptotic level. The overtraining trials strengthen the response of attending to the relevant stimulus dimension and thereby increase its resistance to extinction. By consistently attending to the relevant stimulus dimension in early reversal learning the overtrained





S establishes appropriate choice responses while still attending to the effective stimuli ( $S^+$  and  $S^-$ ).

Nonovertrained Ss on the other hand quickly extinguish attending to the relevant stimulus dimensions and attend to other stimulus dimensions before reverting to the relevant ones. Mackintosh describes the two processes of discrimination learning in terms of "switching in" and "switching out analyzers."

First an analyzer specific to the relevant stimulus dimension is switched in, and secondly approach and avoidance responses are attached to the outputs of the analyzer representing the positive and negative stimuli. Overtraining is assumed to have the effect of strengthening the first process so that the analyzer remains switched in after the overt choice responses have been extinguished, thus ensuring that the problem will still be solved in terms of the relevant dimension. (Mackintosh, 1963, p. 127-128)

Within the framework of the attention model several variables have been found to be determinants of reversal performance, indicating that reversal performance is not only a function of amount of training and reward. Some of these variables are the predominance of the relevant cues within the Ss discriminative repertoire (Mackintosh, 1965b), phylogenetic level (Mackintosh, 1965b), presence of irrelevant cues (Mackintosh, 1963), and type of reversal shift (Mackintosh, 1962).

A major assumption of the model is that the facilitative effect of overtraining leading to the ORE occurs in





the acquisition phase and is not due to faster extinction of the original discrimination. According to Mackintosh (1965a) "Overtraining facilitates reversal of a simultaneous visual discrimination not because of, but in spite of, its effect on extinction." (p.131). He states that the ORE occurs not because of faster extinction, but in spite of increased resistance to extinction. Although there are studies in which overtraining has resulted in increased resistance to extinction (e.g., D'Amato & Jagoda 1962), there are many studies in which overtraining has resulted in decreased resistance to extinction. Mackintosh recognizes that in runway studies (e.g., Hill & Spear, 1963; Ison, 1962; Wagner, 1963), overtraining has been found to reduce resistance to extinction, when this resistance to extinction is measured by running speed in the runway. He asserts however that in discriminative learning, overtraining leads to increased resistance to extinction, when resistance to extinction is measured by the number of trials in reversal in which the animals continue to select the originally positive stimulus (perseverative errors), or when it is measured by the number of trials to an extinction criterion. In three discrimination studies (D'Amato, Schiff & Jagoda, 1962; Mackintosh, 1962, 1963) overtraining led to more perseverative errors or trials to an extinction criterion (i.e. increased resistance to extinction) than nonovertraining; in two of these three studies (Mackintosh, 1962, 1963),



but not in the other, overtraining also led to faster reversal learning. However, in two other discrimination studies (Kendler & Kimm, 1964, 1967) overtraining (with large, but not with small reward) led to fewer perseverative errors than criterion training (i.e., decreased resistance to extinction), and in another study (Birch, Allison & House, 1963) amount of acquisition training did not affect number of perseverative errors. Latency measures during the experimental extinction of a discrimination have been found to be larger (decreased resistance to extinction) for overtrained than for nonovertrained Ss (Mackintosh, 1963). These six studies show that in discrimination learning overtraining has not consistently led to increased or decreased resistance to extinction, when resistance to extinction is measured by trials to an extinction criterion, perseverative errors, or by latencies.

Clearly, the attention model differs from the extinction hypothesis as to the locus of the facilitative effect of overtraining in subsequent reversal learning. The locus of the facilitative effect for the attention model is in the acquisition phase, while the locus for the extinction hypothesis is in the extinction (of the original learning) part of reversal learning.

The present experiment was designed within the framework of the extinction hypothesis of the ORE. This



experiment provides a test of whether a critical determinant of the ORE is the extinction of original learning in reversal learning.

If an ORE is obtained because the situation is such that the original response extinguishes more quickly, then an ORE should occur in Ss manipulated in acquisition by conditions which are known to lead to faster extinction. The effects of such manipulations (i.e., overtraining and large reward magnitudes) should be similar both in extinction behaviour for Ss who have an extinction phase between acquisition and reversal, and in reversal behaviour for Ss who do not have an extinction phase. An ORE in the usual sense should occur in reversal for large reward, nonextinction phase Ss; an OEE (over-learning extinction effect - i.e., faster extinction for overtrained animals) should occur for large reward Ss in the interpolated extinction period, followed by an ORE in reversal. If such data are obtained, the extinction hypothesis of the ORE, rather than the attention model explanation of the ORE, will be supported. Further support for the extinction hypothesis of the ORE would be obtained if Ss with an interpolated extinction period reverse more easily than Ss without an interpolated extinction period. The specific hypotheses that were tested were:

In extinction

1. Larger latencies and more errors were predicted for





larger acquisition magnitudes of reward.

2. Larger latencies and more errors were predicted with overtraining, in large reward groups, but not in small reward groups.

In reversal

1. Smaller latencies and fewer trials to criterion were predicted for the larger acquisition magnitudes of reward.

2. Smaller latencies and fewer trials to criterion were predicted with overtraining, than without overtraining, in large reward groups, but not in small reward groups.

3. Smaller latencies and fewer trials to criterions were predicted for groups with an interpolated extinction period, than for groups without such a period.



## Method

### Subjects

The subjects were 80 male albino rats of the Sprague-Dawley strain. They were about 70 days old at the beginning of the experiment. During the experiment one S of group 100-4E was discarded when it became unmanageable on the seventh day of extinction.

### Design

The design was basically a 2 x 3 factorial in which the independent variables were two levels of acquisition training (40 or 100 trials) and three levels of reward magnitude (2, 4, or 8 45mg. Noyes pellets). These six groups (40-2E, 40-4E, 40-8E, 100-2E, 100-4E, 100-8E) received first 40 or 100 acquisition trials, then 60 extinction trials, and finally reversal training to criterion. In addition to these six groups there were two groups (40-8NE and 100-8NE) who had either 40 or 100 acquisition trials with a reward magnitude of 8 pellets, and then proceeded directly to reversal training. Each of the eight groups had 10 randomly assigned Ss. Assignment to groups was done on the basis of a table of random numbers. The eight groups are shown in Table 1.



Table 1  
The experimental design

	Extinction			No extinction
	2	4	8	8
Reward Magnitude				
Trials				
40	40-2E	40-4E	40-8E	40-8NE
100	100-2E	100-4E	100-8E	100-8NE

The dependent variables used were starting and running latencies in acquisition and extinction, number of errors in acquisition and extinction, trials to criterion in reversal, and starting and running latencies for the first 10 trials of reversal.

#### Apparatus

The experiment was conducted in a room adjacent to the animals' living quarters. Temperature and humidity were kept relatively constant and were approximately the same level in both rooms. Illumination in the experimental room was provided by a 80 watt fluorescent light 6 feet above the apparatus.

Pretraining. The apparatus used for pretraining was a straight alley which was 4" wide, 5½" high, and 55" long. It was constructed of wood, painted medium grey, and covered with plexiglass. The alley could be divided into 5





compartments by plexiglass guillotine doors. All except the first compartment (start box) contained a food cup.

Training. The discrimination apparatus was a single unit T-maze. The stem of the maze was 25" long. The first 7" of the stem comprised the start-box, which could be closed off from the rest of the stem by a guillotine door. The arms of the maze were 20" long, of which the last 10" comprised the goal-boxes. Each goal-box could be separated from the rest of the arm by guillotine doors. A further guillotine door was located at the end of the stem to prevent retracing into the stem after entering one of the arms. The entire maze was 4" wide and 5" high, and was covered with meshed wire, except for the start and goal boxes, which were covered with plexiglass. The stem of the maze was painted grey. Black and white inserts were constructed of  $\frac{1}{4}$ " plywood, which could be put in the arms of the maze, allowing for the spatial distribution of the discrimination stimuli (black-white). The inserts covered the walls and the floor of the arms and could partly be seen while the S was still in the stem portion. A timer that was started by the raising of the start door and stopped by a photoelectric cell located 6" beyond the door measured starting latency. A second timer that was started by the first photocell and stopped by photocells located 2" before the goal boxes measured combined running and choice latencies.



## Procedure

Animals were obtained from the supplier when they were 60-65 days old and weighed between 175 and 200 grams. They were housed two to a cage and were put on ad lib food and water. Food deprivation began three days after arrival and five days before the pretraining. Each animal was handled every day and weighed every other day throughout the experiment. During the experiment the differential reinforcement was taken into account in determining the food rations of the animals. The animals' daily food ration including rewards in the maze was 10 grams. Each animal was run at the same time of day, within half an hour, throughout the experiment. Twenty minutes after each day's trials, the Ss were given their daily food rations. When they had completed the experiment eight animals from different groups were given free access to food and their ad lib weight was determined 10 days later. Comparison of deprivation and ad lib weight showed that the deprivation weight was 86% of the ad lib weight.

Pretraining. Each S was given 1 trial daily for 3 days in the pellet training alley, in which a trial was defined as progressing from the start box to the fifth (last) goal box. The animal was put in the start box and the first door was raised and lowered after the S had entered the second compartment. After the S had eaten the two pellets in the second compartment it was allowed to



progress to the next compartment, and so on to the fifth compartment. On the fourth day of pretraining, each S was given 3 free-choice test trials in the T-maze. On the basis of these trials the animals' nonpreferred brightness (black or white) was determined, which became the positive stimulus.

Training. The Ss were given 5 trials daily in all stages of the experiment. The intertrial interval of about 20 minutes were spent in the Ss home cages. The Ss were given 40 or 100 acquisition trials on the brightness discrimination. All groups, except groups 40-8NE and 100-8NE, then received 60 extinction trials, followed by reversal training, while groups 40-8NE and 100-8NE proceeded directly from acquisition to reversal. The criterion for reversal learning was 9 out of 10 consecutive trials correct. In acquisition and reversal a correction procedure was used allowing the S to retrace in the arms of the maze if he made the wrong choice. When the S had entered the correct goal box, the goal box door was closed. As soon as the S had eaten the reward, it was removed from the goal box to the home cage. Reversal procedures were identical to acquisition procedures except that in reversal the opposite brightness stimulus was rewarded. Extinction procedures were the same as acquisition procedures except that in extinction there was no reward, the S was not allowed to retrace once it had entered either goal box, and it was







removed from the maze if it failed to enter a goal box within 90 seconds of raising the start door. Such responses were recorded as time errors.

The position of the black and white discriminanda on any one trial throughout the experiment was determined by a random order. The restrictions on this random order were that on any 10 trials (2 days) the number of times the positive and negative stimuli appeared on either side was 5, and that no more than 2 consecutive trials would be rewarded on the same side.



## Results

The results are divided into four parts: acquisition, overtraining, extinction, and reversal.

Acquisition. The acquisition data were analyzed in terms of starting and running latencies for 40 acquisition trials and in terms of number of correct daily trials. A repeated measures analysis of variance of correct daily trials yielded a significant effect due to days, magnitude of reward, and a significant days x reward interaction, indicating that the form of the acquisition curves differed for the three magnitudes of reward. A trend analysis of the linear and quadratic components of the days x reward interaction showed that the form of the group curves differed both linearly and quadratically. A summary of the analysis of variance is presented in Table 2. Figure 1 shows the acquisition performance of the four reward groups in terms of number of correct daily trials. It can be seen that large reward (8) Ss learned the discrimination fastest, medium reward (4) Ss were intermediate, and small reward (2) Ss learned the discrimination slowest. Repeated measures analyses of variance of starting latencies and running latencies in acquisition (See Table 3 and 4) indicated a significant effect only due to days; the latencies decreased with acquisition days.

Overtraining. A repeated measures analysis of variance of errors in overtraining is summarized in Table 5 and



TABLE 2

Trend analysis of variance of daily  
correct trials in acquisition for the  
three reward groups

Source	SS	df	MS	F	P
Reward (R)	46.62	2	23.31	10.89	.001
Subj. w. groups	121.98	57	2.14		
Days (D)	303.47	7	43.35	48.73	.001
D x R	25.61	14	1.83	2.06	.01
D x Subj. w. groups	354.93	399	.89		
D x R (linear)	8.31	2	4.15	4.66	.01
D x (quadratic)	10.30	2	5.15	5.79	.01
D x R (cubic)	1.60	2	.80	.90	---





TABLE 3

Repeated measures analysis of variance of starting latencies for the three reward groups in acquisition

Source	SS	df	MS	F	P
Reward (R)	734.93	2	367.47	1.44	---
Subj. w. groups	14504.56	57	254.47		
Days (D)	41331.95	7	5904.56	42.66	.001
R x D	2326.48	14	166.18	1.20	---
D x Subj. w. groups	55224.56	399	138.41		



TABLE 4

Repeated measures analysis of variance of  
running latencies in acquisition (for three  
reward groups only)

Source	SS	df	MS	F	P
Reward (R)	2.01	2	1.01	.06	---
Subj. w. groups	939.60	57	16.48		
Days (D)	1735.35	7	14.72	21.18	.001
D x R	206.04	14	14.70	1.25	---
D x Subj. w. groups	4669.95	399			

TABLE 5

Repeated measures analysis of variance for  
errors in overtraining

Source	SS	df	MS	F	P
Reward (R)	2.45	3	.82	1.90	----
Subj. w. groups	15.49	36	.43		
Days (D)	1.82	11	.17	1.58	----
D x R	3.52	33	.11	1.02	----
D x Subj. w. groups	41.41	396	.11		



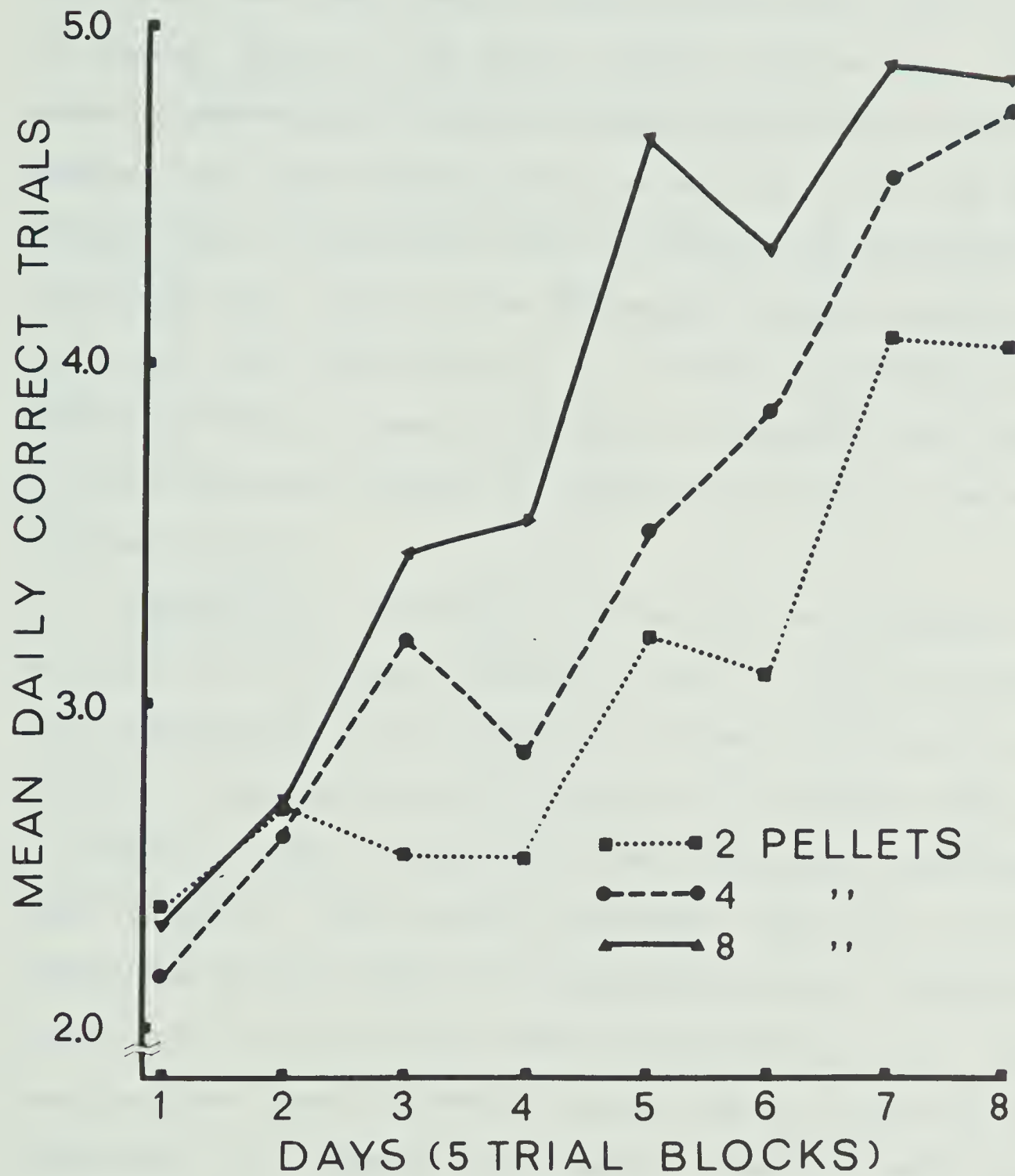


FIG. 1. Mean daily correct trials in acquisition for three reward magnitudes (groups 40-2E and 100-2E; 40-4E and 100-4E; 40-8E and 100-8E).





indicates that there was no significant effect due to amount of reward, days, or the days x reward interactions. The average percentage of errors during overtraining for the small, medium, and large reward groups were 4.5%, 2.1%, and 2%, respectively, indicating that the error rate in overtraining was quite low, and that the difference between reward groups was small (see also Figure 2 ). The non-significant days effect and days x reward interaction indicates that performance of the groups had reached an asymptotic level at the beginning of overtraining.

Extinction. Extinction performance was analyzed in terms of starting and running latencies, and in terms of error scores (i.e., responding to the stimulus that was negative in acquisition). Repeated measures analyses of variance presented in Tables 6 and 7 showed that both latencies increased over days ( $p < .001$ ). For starting latencies there was a significant effect due to the number of acquisition trials (40 and 100,  $p < .03$ ) and to acquisition reward magnitude ( $p < .01$ ). Overtraining and large and medium reward led to larger starting latencies (i.e., faster extinction), as can be seen graphically in Figures 3 and 4. Figure 4 shows that the effect begins quite early for medium and large reward groups, which remain different from the small reward group throughout the extinction period. There were no significant effects in running times, except for the days effect, indicating that the running latencies increased similarly for all groups.



TABLE 6

Repeated measures analysis of variance  
of starting latencies (in seconds) in extinction

Source	SS	df	MS	F	P
Training (T)	1534.89	1	1534.89	4.95	.03
Reward (R)	2725.96	2	1362.98	4.39	.01
R x T	906.44	2	453.22	1.46	---
Subj. w. groups	16755.63	54	310.29		
Days (D)	5935.41	11	593.58	4.45	.001
D x T	2306.58	11	209.69	1.73	---
D x R	1445.43	22	65.70	.54	---
D x T x R	2374.86	22	107.95	.89	---
D x Subj. w. groups	71984.00	594	121.18		



TABLE 7

Repeated measures analysis of variance of  
running latencies (in seconds) in extinction.

Source	SS	df	MS	F	P
Training (T)	1195.62	1	1195.62	.08	---
Reward (R)	69302.68	2	34651.34	2.41	---
R x T	34722.20	2	17361.10	1.21	---
Subj. w. groups	776735.55	54	14383.99		
Days (D)	287213.16	11	26110.28	17.23	.001
D x T	16617.47	11	1510.92	1.00	---
D x R	40940.34	22	1860.92	1.23	---
D x T x R	29626.77	22	1346.67	.89	---
D x Subj. w. groups	900187.75	594	1515.46		





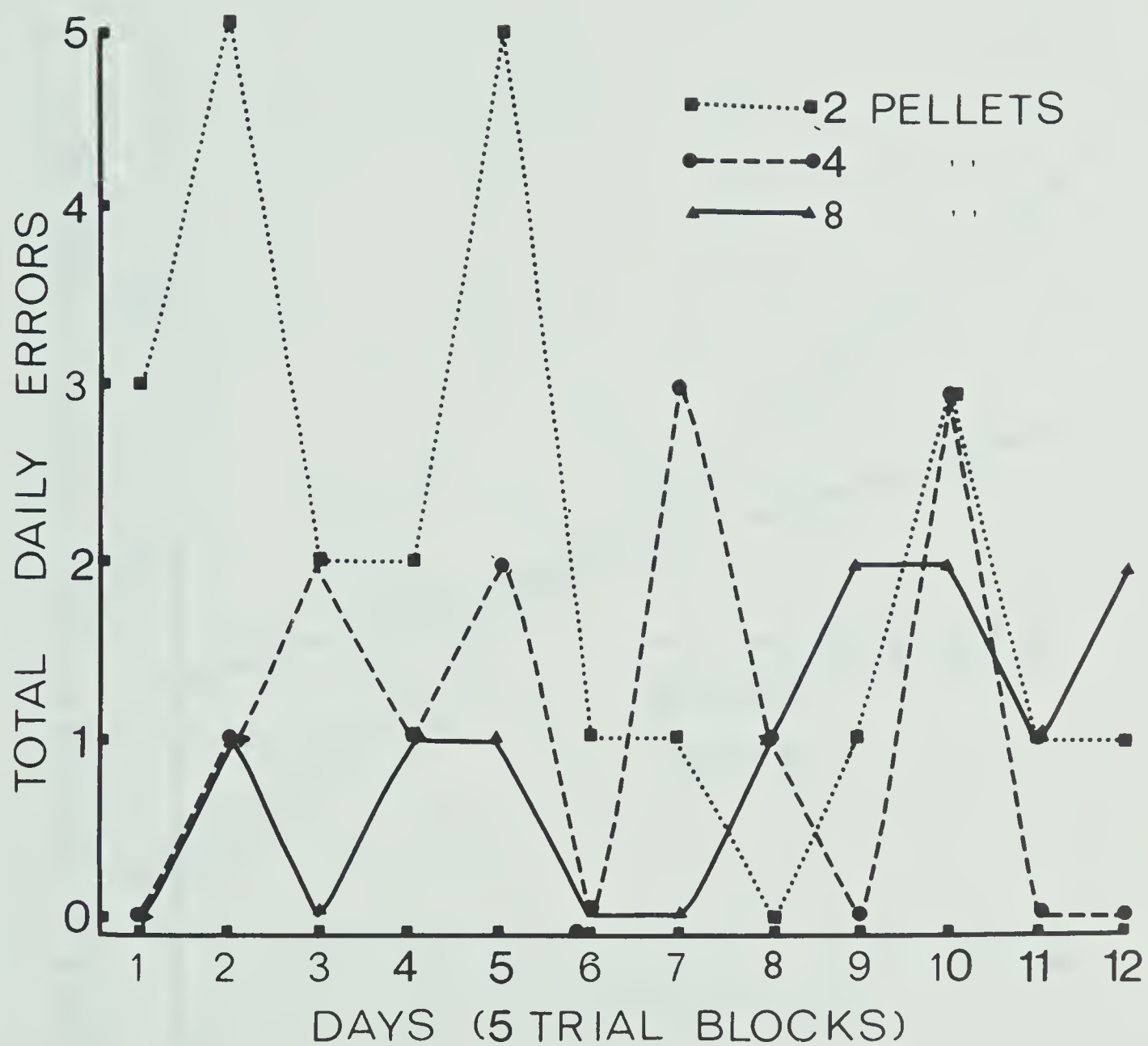


FIG. 2. Total daily errors in overtraining for three reward groups (for each group,  $N = 10$ ).



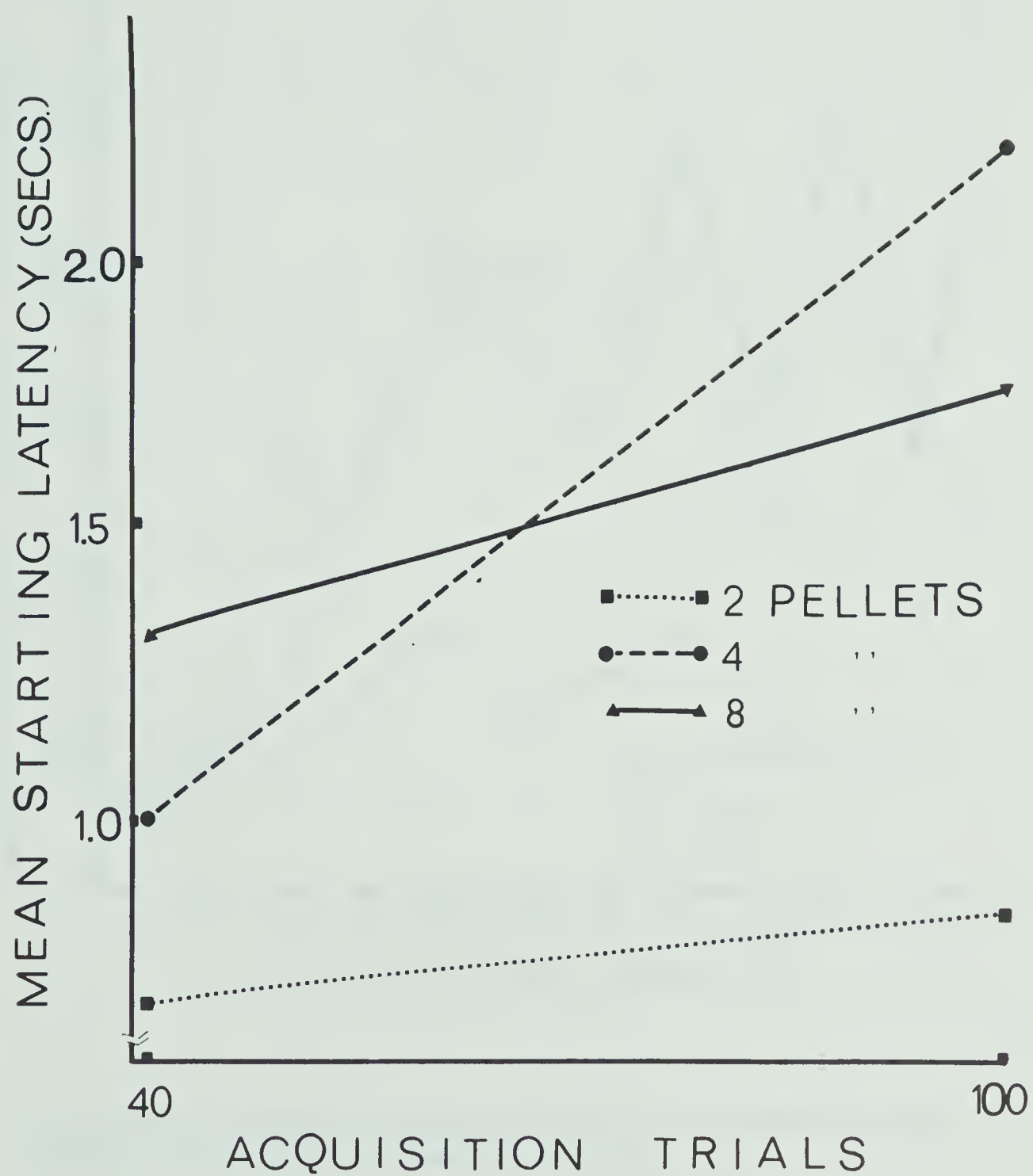


FIG. 3. Mean starting latency in extinction for three reward magnitudes as a function of training level.



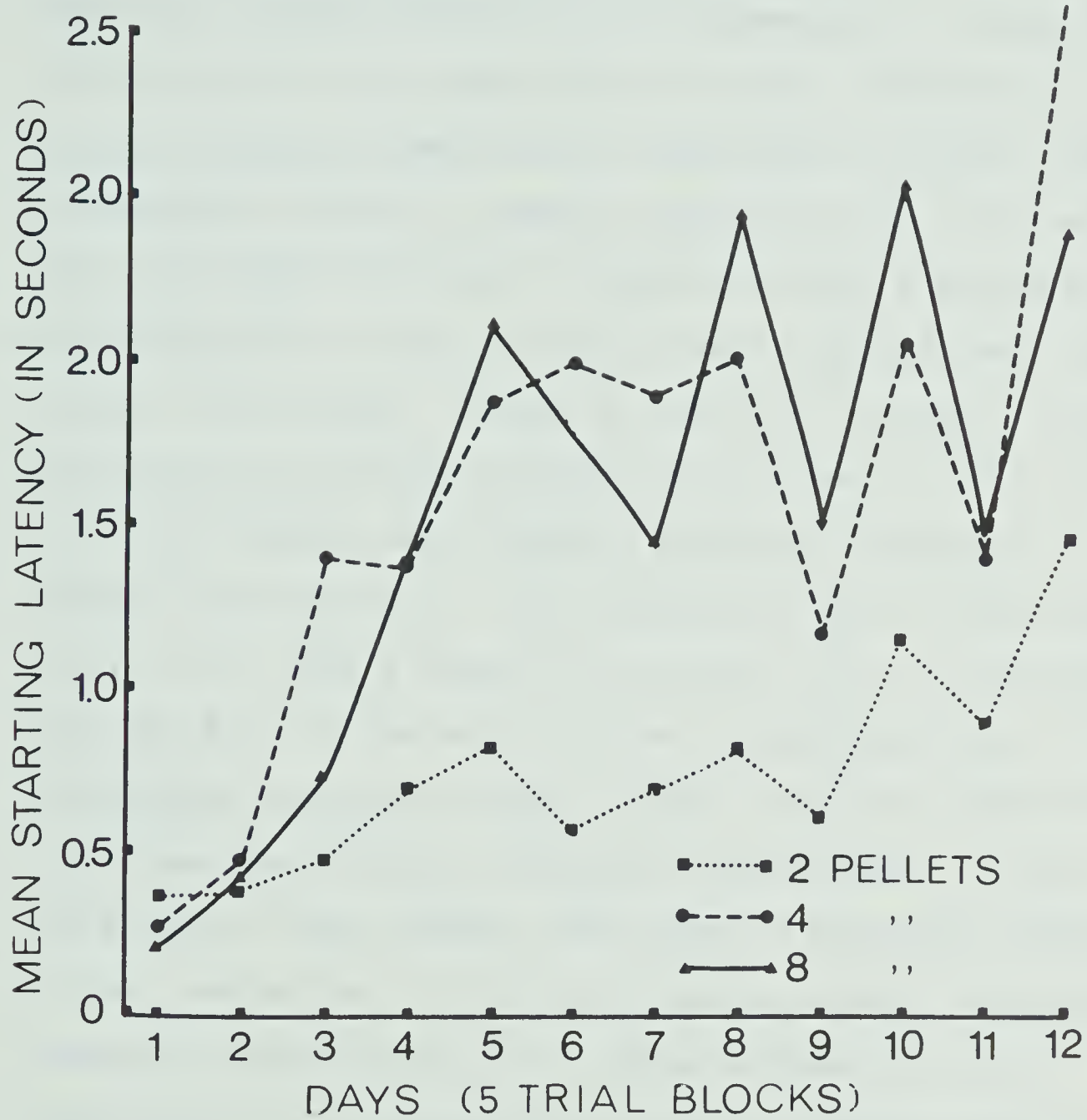


FIG. 4. Mean starting latency in extinction for three reward magnitudes over days.



A summary of the repeated measures analysis of variance of error scores in extinction is presented in Table 8, and means and standard deviations are presented in Table 9. The only significant main effect of days indicates that there was an increase in mean errors over days ( $p < .001$ ). The significant training x reward interaction ( $p < .02$ ) indicates that the number of errors in extinction was a function of the interaction of acquisition reward magnitude and criterion versus overtraining. After 40 trials the number of errors was inversely related to magnitude of reward, while after 100 trials errors were directly related to magnitude of reward (see Figure 5). The significant days x training ( $p < .03$ ) and days x reward interaction ( $p < .02$ ) indicates that the form of the error curves in extinction for the two acquisition training groups, and for the three acquisition reward magnitude groups differed significantly. Figure 6 and Figure 7 show however, that none of the three reward groups, and neither of the two training groups were consistently superior, as is of course indicated by the significance of the main effects of the reward and training.

Another analysis of extinction errors which yielded the same results as the preceding analysis involved an analysis of the Ss' tendency to equalize his responses to the positive and negative stimuli. This tendency was evaluated by obtaining scores of deviation from chance responding (i.e., 50% to either stimulus). The logic for this measure is that extinction





TABLE 8

Repeated measures analysis of variance  
of errors in extinction

Source	SS	df	MS	F	P
Training (T)	.73	1	.73	.23	---
Reward (R)	.47	2	.23	.07	---
R x T	28.17	2	14.08	4.32	.02
Subj. w. groups	176.19	54	3.26		
Days (D)	338.27	11	30.75	31.36	.001
D x T	21.31	11	1.94	1.98	.03
D x R	38.09	22	1.73	1.77	.02
D x T x R	18.73	22	.85	.87	---
D x Subj. w. groups	582.51	594	.98		



TABLE 9

Means and standard deviations of errors in extinction

Groups	Magnitude of Reward							
	2		4		8			
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Acquisition 40	2.16	1.39	1.86	1.27	1.71	1.29	1.91	1.33
Acquisition 100	1.60	1.18	1.83	1.15	2.11	1.37	1.85	1.25
$\bar{X}$	1.88	1.32	1.85	1.21	1.91	1.34		



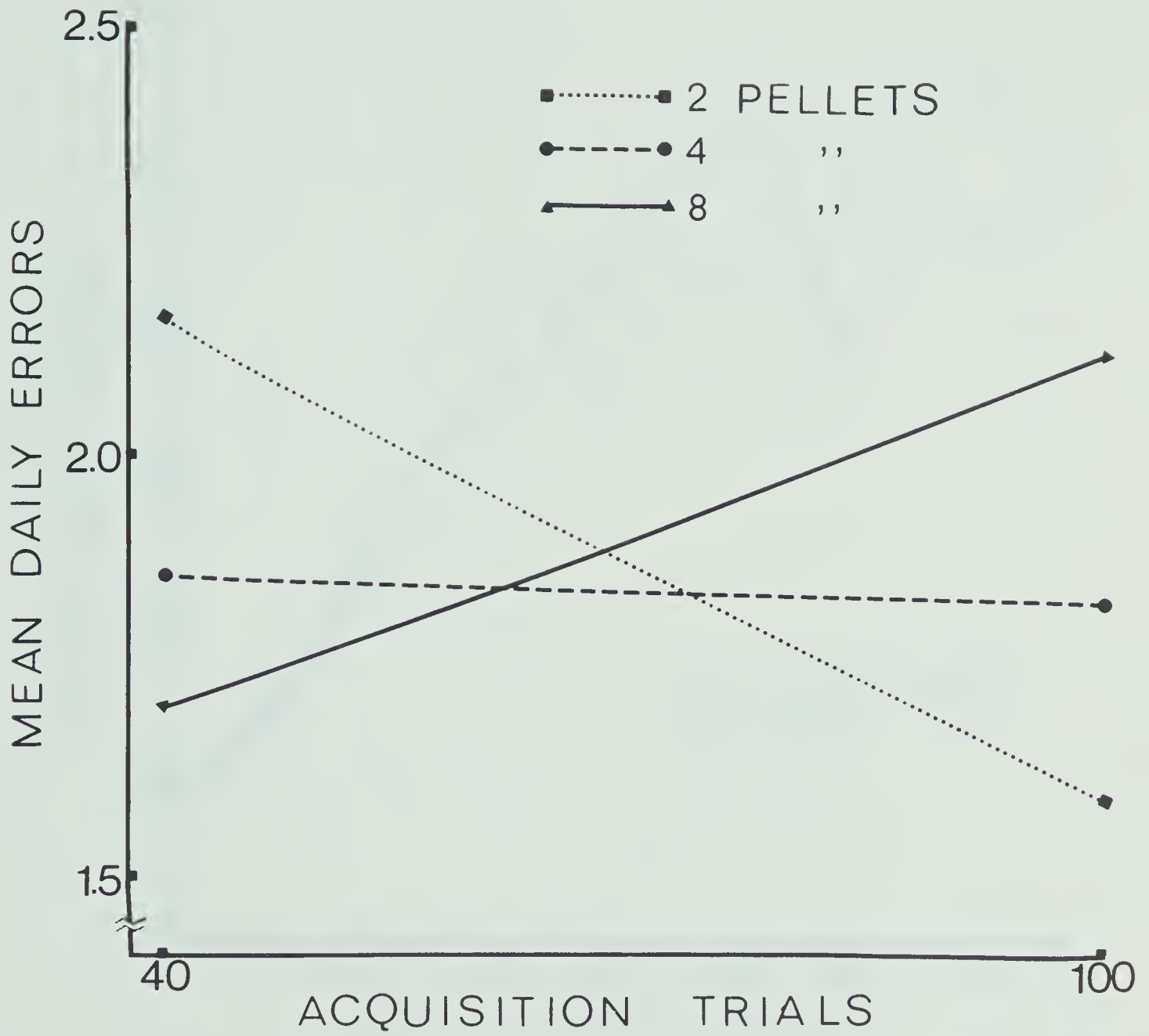


FIG. 5. Mean daily errors in extinction for three reward magnitudes as a function of level of training.





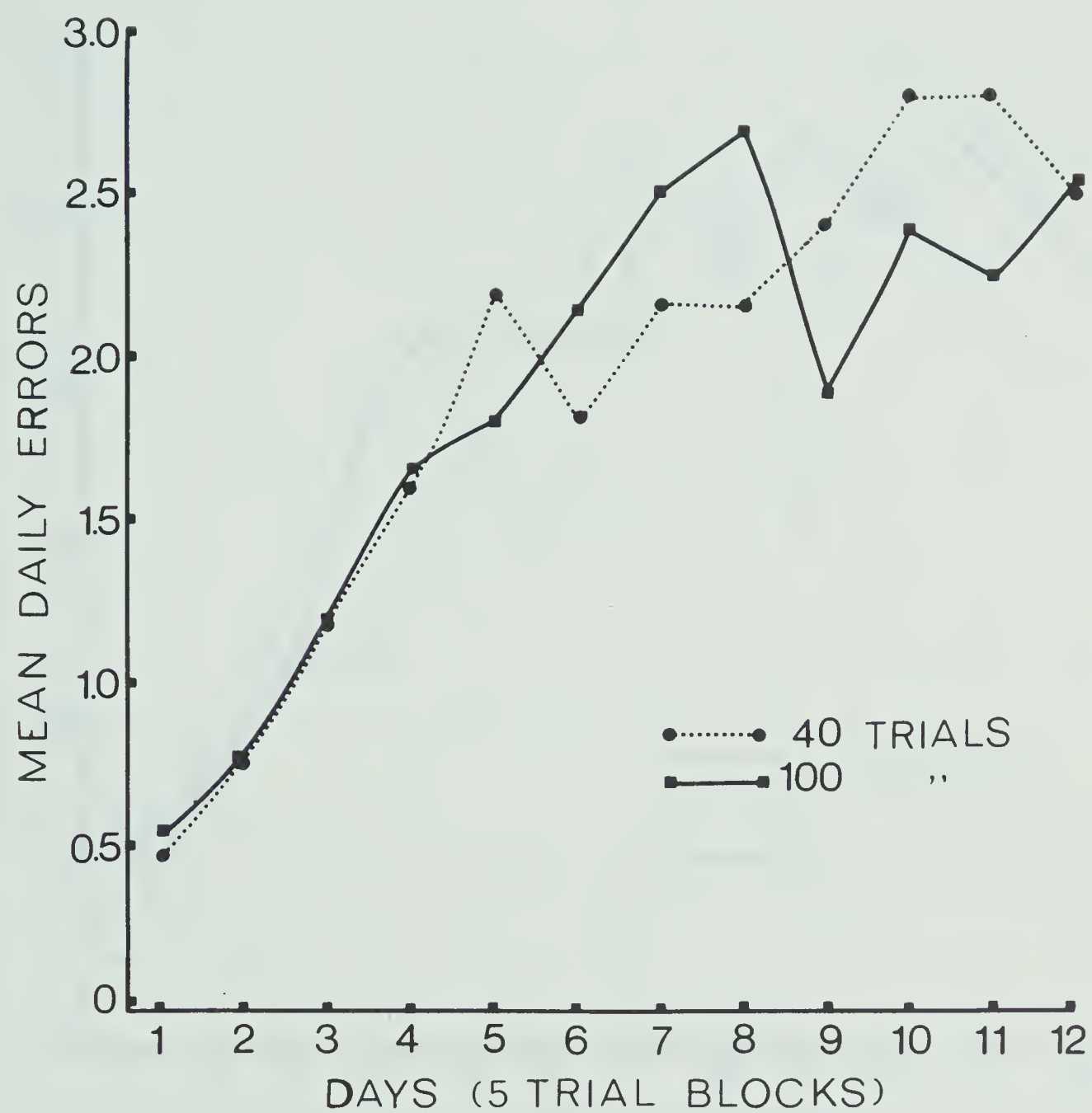


FIG. 6. Mean daily errors in extinction for two levels of acquisition training.



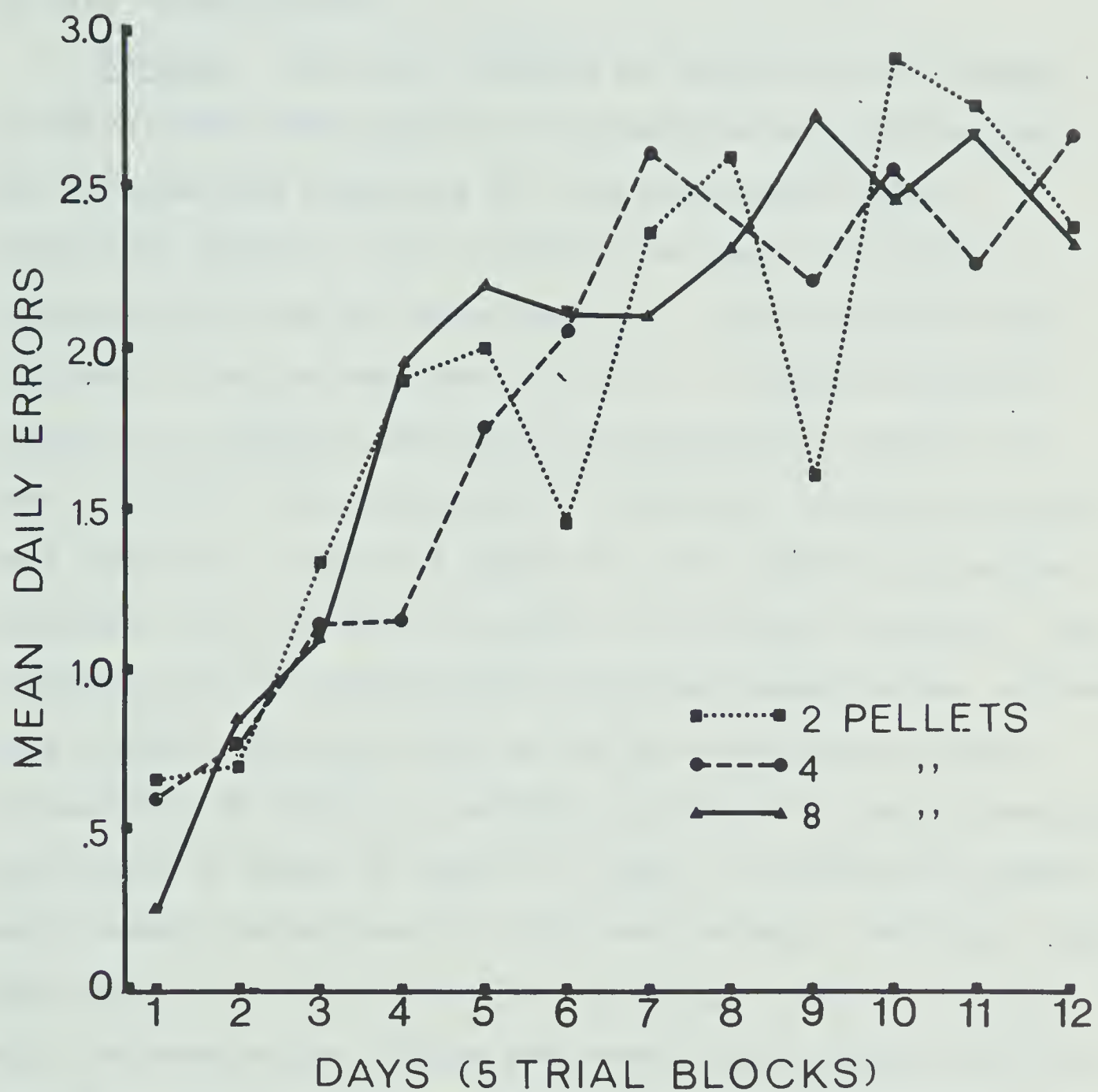


FIG. 7. Mean daily errors in extinction for three reward magnitudes.



can be represented as a progression toward equal response tendencies to both the negative and positive stimulus. The rate at which this equalization occurs gives an index of rate of extinction.

Reveral. The only analysis of latencies in reversal in which there were significant effects other than for days was for starting latencies for the six groups with an extinction period. Only the first two days of reversal training were used in these analyses, since animals began reaching criterion starting on day 2. A repeated measure analysis of variance indicated the significant effects of days ( $p < .001$ ), training ( $p < .04$ ), and days x training ( $p < .02$ ) (see Table 10). Figure 8 shows that the starting latencies decreased over the first two days of reversal training. The latencies for the overtrained groups decreased faster, although they reached the same level as the non-overtrained group. An analysis of trials to reversal criterion of the six extinction groups is shown in Table 11; Table 13, showing the means and standard deviations for this same measure, indicates that no ORE occurred in the six extinction groups. Overall, groups with 100 acquisition trials performed significantly poorer in reversal ( $p < .001$ ) than groups with 40 acquisition trials. A significant reward effect ( $p < .001$ ) indicated that, overall, large and medium reward magnitude groups performed better in reversal than small reward magnitude. The results best describing the relationship of the six groups in the analysis was the significant interaction (see Figure 9) between



TABLE 10

Repeated measures analysis of variance of  
starting latency for the first two days in  
reversal of six groups with an extinction  
period.

Source	SS	df	MS	F	P
Training (T)	74.77	1	74.77	4.30	.04
Reward (R)	62.86	2	31.43	1.81	---
R x T	7.90	2	3.95	.23	---
Subj. w. groups	93.84	54	17.37		
Days (D)	283.11	1	283.11	18.23	.001
D x T	92.12	1	92.11	5.93	.02
D x R	38.71	2	13.35	1.25	---
D x T x R	94.90	2	4.75	.31	---
D x Subj. w. groups	838.52	54	15.53		





TABLE 11

Analysis of variance of trials to reversal criterion  
for groups with interpolated extinction.

Source	SS	df	MS	F	P
Trials (T)	2220.42	1	2220.42	9.08	.001
Reward (R)	4997.50	2	2498.75	10.22	.001
R x T	3270.83	2	1635.42	6.68	.001
Error	13202.50	54	244.49		
Total	23691.25	59			

TABLE 12

Analysis of variance of trials to reversal criterion  
for groups 40-8E, 40-8NE, 100-8E and 100-8NE

Source	SS	df	MS	F	P
Training (T)	2975.62	1	2975.62	11.18	.01
Extinction (E)	5175.62	1	5175.62	19.45	.01
E x T	765.62	1	765.62	2.88	---
Error	9577.50	36	266.04		
Total	18494.37	39			



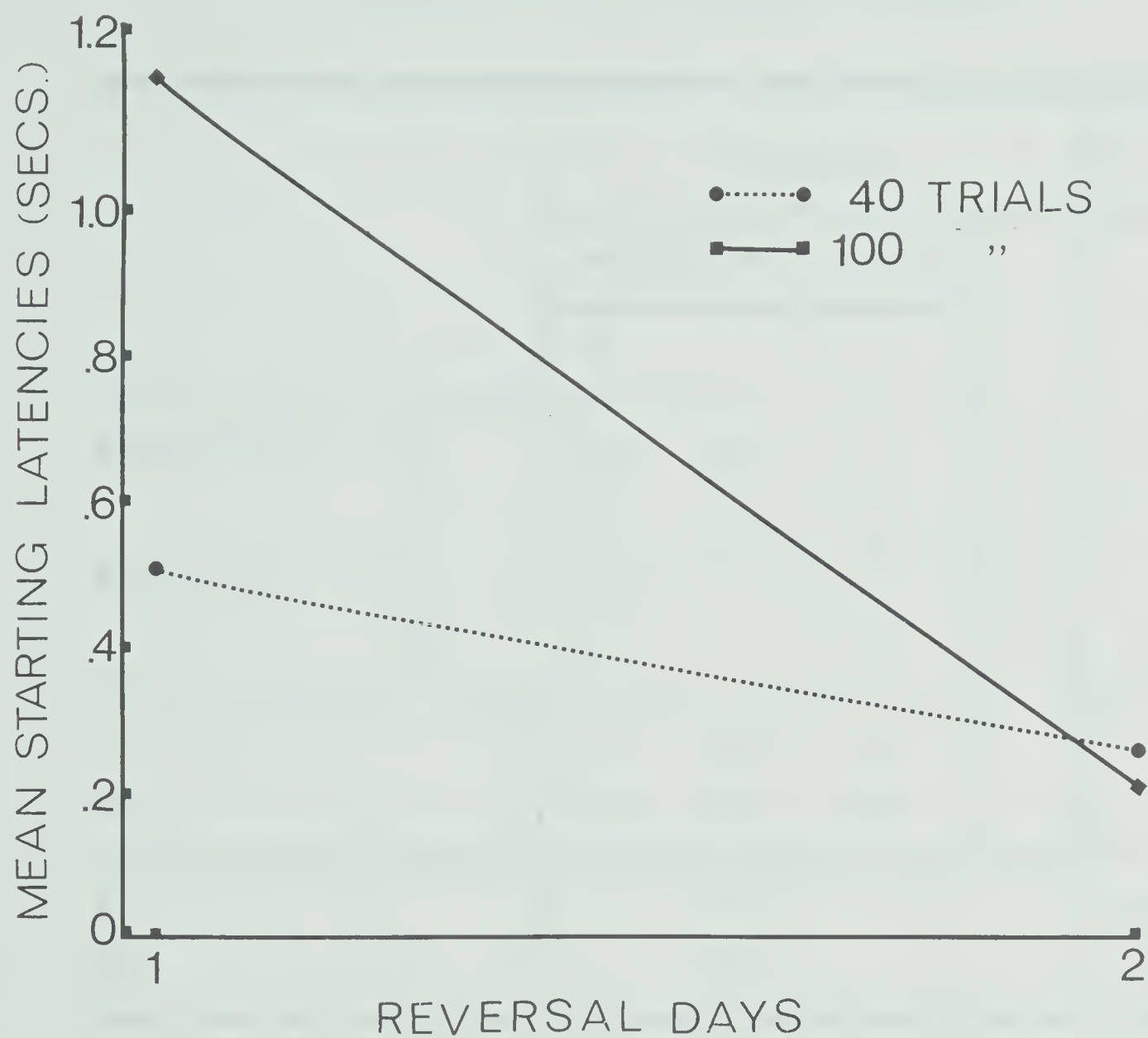


FIG. 8. Mean starting latency for two days of reversal for two levels of acquisition training.



TABLE 13

Means and standard deviations of trials to  
criterion for all groups in reversal

	Extinction				No Ext.
	Magnitude of reward				
	2	4	8		8
Acquisition 40 $\bar{X}$	39.0	42.0	37.0	39.5	71.5
SD	13.1	14.4	15.3	13.7	21.9
Acquisition 100 $\bar{X}$	70.0	31.0	31.5	44.1	45.5
SD	23.7	8.1	15.1	23.4	12.1
$\bar{X}$	54.5	36.5	39.7		
SD	24.5	15.3	25.0		
$\bar{X}$	41.7				58.5
SD	23.2				21.7





magnitude of reward and level of acquisition training ( $p < .01$ ). Using Scheffe's test for multiple comparisons it was found that group 100-2E differed significantly from group 40-2E; (for  $p < .05$ ,  $F' = 20.55$ ,  $F = 30.076$ ). Group 100-2E required more trials to reach the reversal criterion than group 40-2E. The difference in the number of trials to reach the reversal criterion between overtrained and nonovertrained large and medium reward groups was in the predicted direction, but did not reach significance.

An analysis of variance (See Table 12 and Figure 10) of the two large reward groups with extinction (40-8E and 100-8E) and without extinction (40-8NE and 100-8NE) showed that an interpolated extinction stage decreased the number of trials to reversal ( $p < .01$ ). In this analysis there was also a significant effect due to level of training ( $p < .01$ ); the overtrained groups (100-8E and 100-8NE) reversed faster than the non-overtrained groups (40-8E and 40-8NE). Scheffe's test for multiple comparisons showed that the group 100-8NE differed significantly from group 40-8NE in that overtraining led to fewer trials to criterion (for  $p < .05$ ,  $F' = 12.33$ ,  $F = 12.71$ ). In comparing groups 100-8E and 40-8E it was found that overtraining led to fewer trials to criterion, but not significantly so.



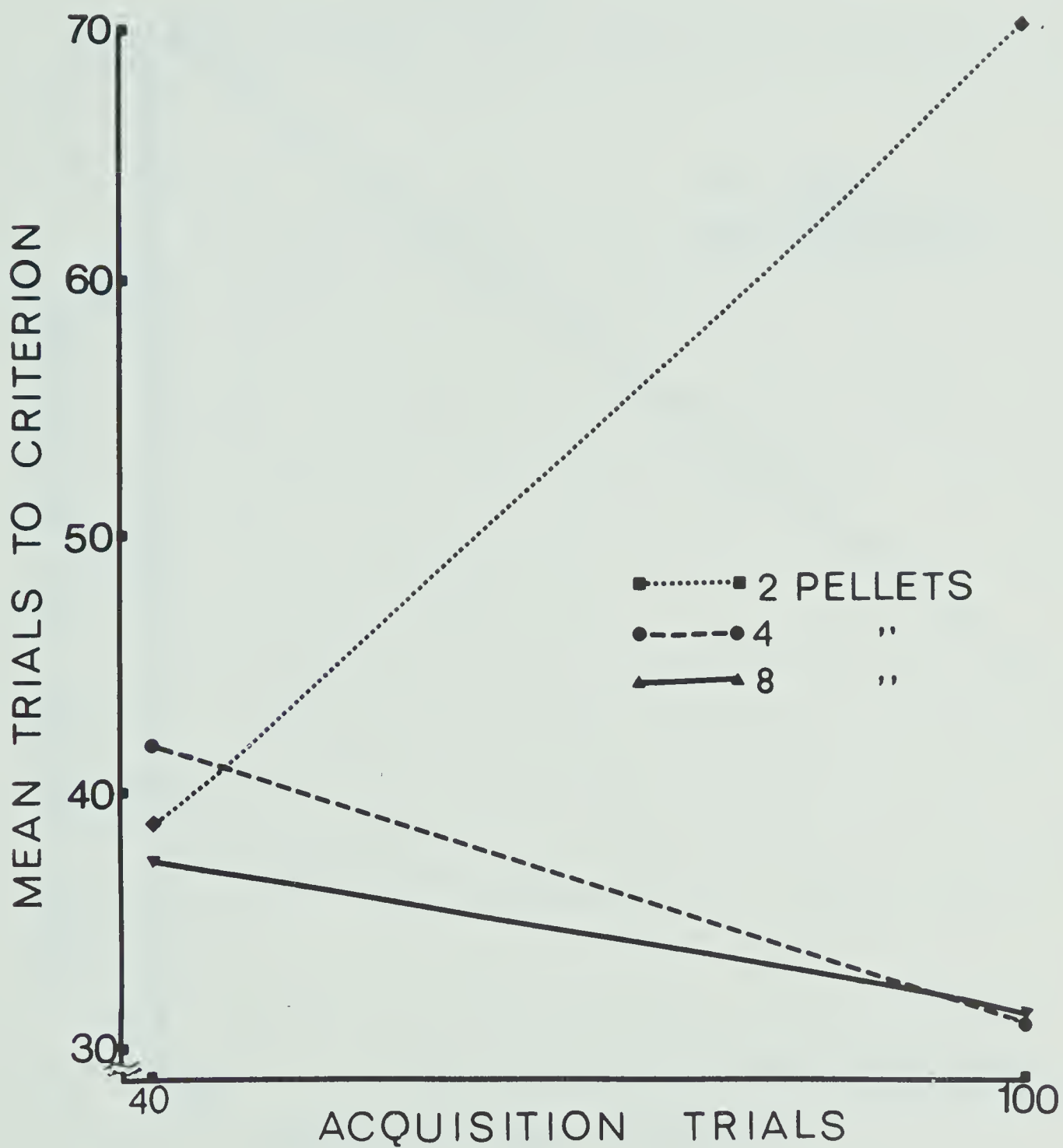


FIG. 9. Mean trials to reversal criterion for three reward magnitudes as a function of level of acquisition training for groups with interpolated extinction.



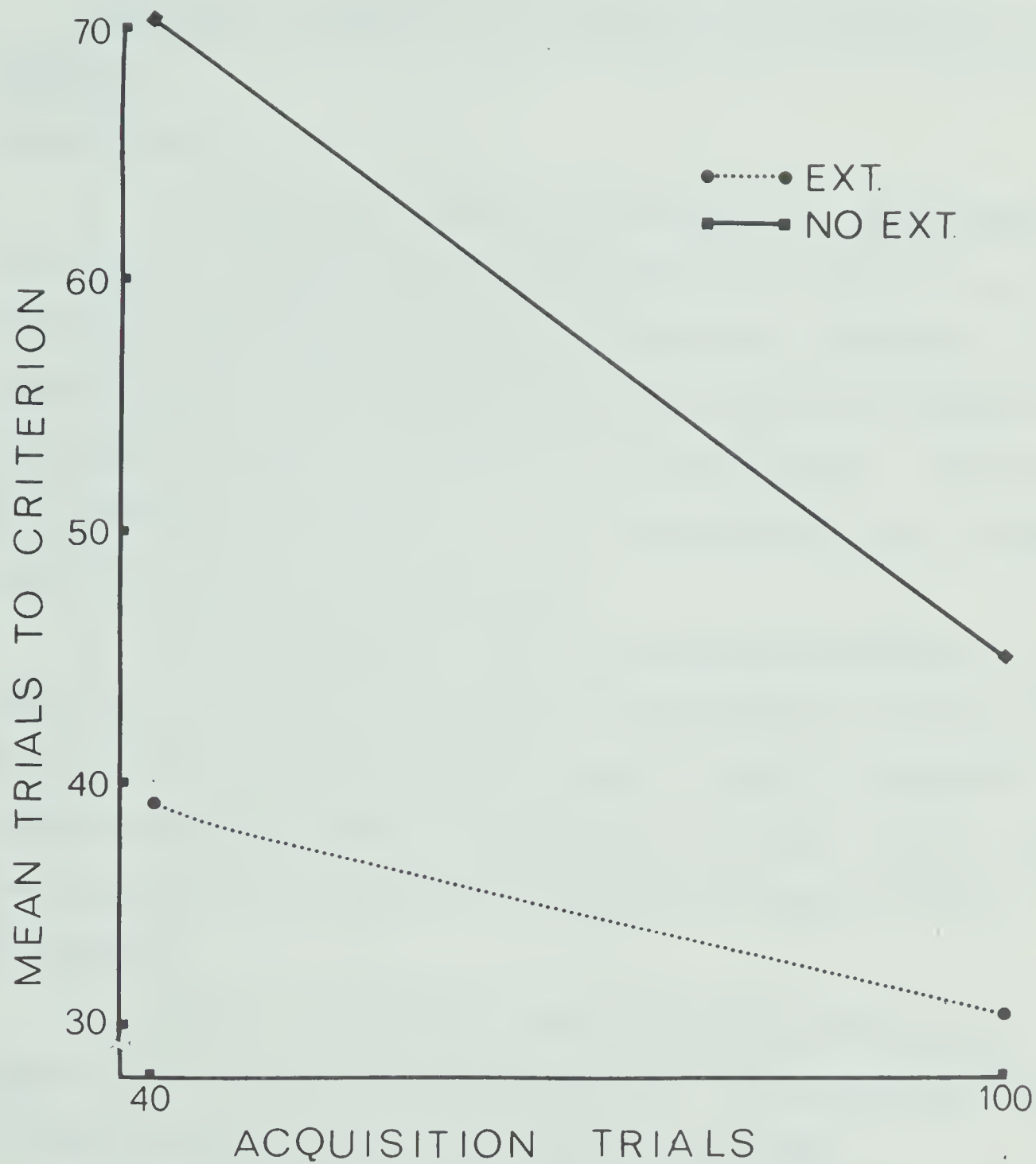


FIG. 10. Mean trials to reversal criterion of large reward groups with and without extinction as a function of level of acquisition training.



## Discussion

The major findings of the study can be summarized as follows:

### In extinction

1. As predicted, groups with medium and large magnitude of reward in acquisition extinguished more easily, as is indicated by larger starting latencies in extinction, compared to small reward groups. The predicted similar effect of magnitude of reward on errors in extinction did not occur. Although not predicted, it was found that overtraining led to larger starting latencies in extinction.

2. The predicted interaction between magnitude of reward and level of acquisition training occurred with error scores, but not with latencies in extinction. Errors increased (i.e., faster extinction) with overtraining for large reward groups, but decreased with overtraining for small reward groups.

### In reversal

1. Trials to criterion were an inverse function of magnitude of reward, as was predicted. The predicted effect of reward magnitude on latencies was not found.

2. The predicted interaction between magnitude of reward and level of acquisition training on trials to criterion was significant, but the form of the interaction was not as predicted. For medium and large reward groups which had an interpolated extinction period there were no significant differences due to the level of acquisition training, although





the direction of the differences was as predicted. For large reward non-extinguished groups, the predicted significant ORE was obtained. For small reward extinguished groups a reverse ORE was found. The predicted interaction for latencies was not found.

3. As predicted, an interpolated extinction period significantly decreased trials to criterion, although the predicted effect on latencies was not found.

An additional finding in acquisition was that groups with larger magnitude of reward learned the brightness discrimination faster.

Acquisition and overtraining. The results of performance during the 40 acquisition trials indicate that magnitude of reward affects the rate of discrimination learning. The results agree with previous findings, such as those of Schrier (1956), Pubols (1961), Lawson et al (1959), and Clayton and Koplin (1964). In these studies, as well as in the present experiment, errors were in inverse function of magnitude of reward. A further conclusion of some previous studies has been that asymptotic performance for different reward groups continued to differ beyond a performance criterion. In the present experiment however, performance in terms of errors in overtraining was not distinguishable on the basis of amount of reward. At the end of the 40 acquisition trials all groups had reached about the same asymptote of performance as can be seen by examining Figure 2 and by the nonsignificant differences



between magnitude groups in the analysis of errors in overtraining. Throughout overtraining, reward magnitude had no significant effect on performance. A possible explanation of this discrepancy between previous studies and the present results is that previous studies did not have a sufficient number of trials and therefore did not reach the final common asymptote of performance.

The acquisition results suggest that reversal learning will also be affected by the magnitude of reward, since reversal can be considered the acquisition of new learning. A study by Kendler and Kimm (1967) however, has shown that acquisition magnitude of reward is more effective in determining reversal performance than is the magnitude of reward in reversal. In the Kendler and Kimm study (1967) magnitude of reward in reversal was varied factorially for each reward magnitude in acquisition. The reversal results showed that while reversal magnitude of reward did affect the number of trials to the reversal criterion, the major differences in reversal performance were due to the magnitude of reward in acquisition.

Extinction. From Theios and Blosser's (1965a) model, it was predicted that overtrained Ss would be less resistant to extinction than nonovertrained Ss with large reward, but not with small reward. The results support this prediction to some extent, but not entirely. The analysis of errors in extinction showed that with large reward overtrained Ss





extinguished faster than nonovertrained Ss. With small reward, however, overtraining led to slower extinction, whereas Theios and Blosser's model would predict no difference. The results of the small reward groups are then in line with Mackintosh's (1965a) assertion that overtraining of a discriminative task leads to increased resistance to extinction, when resistance to extinction is measured by perserverative errors. With reference to the two theoretical analyses of the ORE, the extinction results for large reward groups support Theios and Blosser's model and for small reward groups support Mackintosh's model.

An unexpected finding of the error data in extinction was that among the nonovertrained groups the small reward group extinguished faster than the medium and large reward groups. A possible explanation for this finding is that the small reward group did not establish a strong response to the positive stimulus in acquisition and therefore extinguished this response more easily than the larger reward magnitude groups. The acquisition curves for the three reward magnitudes showed that while the large and medium reward groups reached asymptotic performance at least on day 7, the small reward groups did not quite reach the same asymptotic performance on day 8, the last day of acquisition.

Starting and running latencies in extinction did not show the predicted interaction effect of acquisition magnitude of reward and amount of acquisition training. For starting latencies all main effects were significant; for large reward groups overtraining led to larger latencies (i.e., faster





extinction). The starting latency results are in line with previous studies which found that large reward led to larger latencies in extinction (Hulse, 1958), and that overtraining also led to larger latencies (Wagner, 1963; Mackintosh, 1963). Starting latency in the present experiment was a more sensitive measure in extinction than running latency, which did not yield any treatment effects; the former showed predicted group differences, while running latency did not. Running latency in the present experiment included time spent at the choice point, which may have cancelled groups differences in running speed in the stem of the maze.

It has been the practice in discrimination experiments to equate the measures of errors and latencies (Birch, 1955), although time measures have been regarded as being more susceptible to motivational variables than choice responses (Hillman, Hunter & Kimble, 1953). The results of this study suggest that in discrimination learning and extinction the two kinds of response measures are not necessarily similar. Mackintosh (1963) has also reported a discrepancy between the two kinds of response measures in the extinction of a reversal habit. He found that overtraining led to more trials to an extinction criterion of choice responses, but to faster extinction in terms of latencies.

Reversal. The only significant effect for latency measures in reversal was due to acquisition training level.



The latency results in reversal agree with those in acquisition, in which also no effect due to magnitude of reward was found. The results of trials to criterion indicated that the only significant difference between the 40 and 100 trial groups of equal reward was in the small reward groups; a reverse ORE was found with small reward magnitude. This finding agrees with two previous studies (D'Amato & Schiff, 1965; Kendler & Kimm, 1967) in which small reward led to a reverse ORE. The conclusion to be drawn is that overtraining with a small reward magnitude leads to a reverse ORE, rather than no difference between criterion and overtrained Ss as predicted by the Theios and Blosser model. The unexpected performance of the 100-2E group is anticipated by its extinction performance. Its running and starting latencies as well as its error scores were the lowest of all groups indicating its great resistance to extinction. Together, these results suggest that reversal learning with small reward is slow because of the great resistance to extinction of the original learning.

For the groups with an interpolated extinction period there was no significant difference between groups 40-4E and 100-4E, and 40-8E and 100-8E, although the mean differences were in the predicted ORE direction. An ORE, however, was found between groups 40-8NE and 100-8NE, which did not have an interpolated extinction period. This finding provides



strong support for the extinction explanation of the ORE since, for these large reward groups, a significant effect due to overtraining was found in extinction, but not in reversal, for groups with an extinction period; and for groups without an extinction period an overtraining effect was found in reversal. This indicates that under conditions that normally produce the ORE, the effect can be reduced by an interpolated extinction phase. In terms of an extinction account of the ORE, this means that the differential resistance to extinction of the groups, as a function of differential acquisition treatment, has been equalized to the extent that its effect no longer leads to a significant ORE.

In extinction, large reward overtrained Ss extinguished faster than large reward nonovertrained Ss, and the overtrained Ss also reversed faster, although not significantly; statistical significance was not reached because of the equalizing effect of the interpolated extinction period. Together with the extinction performance of the small reward groups, these results provide support for the predicted similarity of performance in extinction and reversal.

In conclusion, the results of the present experiment indicate that 1) speed of reversal learning is related to the level of extinction of the original learning, 2) reversal performance can be predicted to some extent from extinction performance and 3) that extinction of original learning is an important process in reversal learning. Since the relationship between extinction performance and





reversal performance only partially predicts reversal performance, the results further indicate that the level of extinction of original learning is not the only determinant of reversal performance. The acquisition data suggest that one further variable determining reversal performance is the magnitude of reward in reversal.

The results of the present experiment favour extinction hypotheses of the ORE and cast some doubt on the attention model analysis of the ORE. Two conditions that have been shown to control the ORE within the framework of the extinction hypothesis are the magnitude of reward and the level of extinction of the original learning. Further, the effect of reward magnitude on reversal learning appears to act primarily through its effect on the extinction of original learning. A complete analysis of the ORE thus needs to take into account the effect of differential extinction of original learning on reversal learning.





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